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(54) **BALER AND METHOD OF BINDING A BALE**

(57) A baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook by the stripper element, where-

in the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, and

- at least the second knot is a loop knot.

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Description

[0001] The present invention relates to a baler and a method of binding a bale. The invention also relates to a baler comprising a bale forming channel, a reciprocating plunger and a binding system for binding a bale in the bale forming channel.

[0002] It is known to provide a baler for pressing bales with a reciprocal plunger, whereby the bale is bound by tying a plurality of twine loops around the bale.

[0003] The twine for binding the bale is supplied by two supplies per twine loop, one for the top side and one for bottom side of the bale. The closing of the loop around the finished bale is done by tying two knots. The basic principle of such a bale binding system is well described in US4074623 and EP2861055. The binding system described in US4074623 uses only one bill hook per twine loop, which produces the two knots sequentially. The binding system described in EP2861055 uses two bill hooks per twine loop that produce one knot per bill hook per cycle and produce the knots simultaneously. The first system described in US4074623 is more compact and less complicated than the second described in EP2861055.

[0004] It is known from prior art that the knots can be of a conventional type or a loop type, as depicted in Figs. 1 & 2. In a conventional knot as depicted in Fig. 1 the cut ends 10 of the twines extend outwards from the knot. In a loop knot as depicted in Fig. 2 the cut ends 10 of the twines are turned back on themselves and caught by the turns of the knot, forming short twine loops 12 on top of the knot. US4074623 is an example of a binding system as described above in which the twines are tied with a conventional knot. EP2861055 is an example of a binding system as described above in which the twines are tied with a loop knot. Conventional knots as well as loop knots are also known from binding systems where there is only one twine supply per (bale binding) loop, and the binding loop is closed by one knot. Binding systems with one twine supply/knot are less favourable because passing the single twine around the bale puts a lot of tension on the twine while baling and during knotting of the twine, which can break the twine or deform the knot.

[0005] The binding of the bale is necessary to hold the bale under compression; the expansion of the bale as it is ejected from the baling channel puts a lot of tension on the binding twine. The breaking resistance of the binding twine and the knot(s) in the twine determine the maximum possible compression of the material in the bale. A high compression is desirable as the higher the compression the more efficiently the bale material can be stored and transported.

[0006] It is known that the breaking force for breaking the twine in or near the knot is less than the breaking force of the twine away from the knot, so if the expanding material of the bale puts too much tension on the binding loop the twine is likely to break in or directly adjacent to the knot, for example at the locations 11 indicated in Fig.

1. This because the twine in and directly adjacent the knot is bent over a small radius and the fibers in the outer part of the bend are subjected to a greater strain and are likely to break first. When the outer fibers break the rest of fibers will also then break.

[0007] Further it is known that the binding twine is twisted and in practice it is always twisted in the same direction, called a Z-twist, as illustrated in Fig. 3.

[0008] A knot can be made "right-handed" or "left-handed" depending on the turning direction of the bill hook. In US4074623 both knots are tied as right-hand knots (the bill hook is turned clockwise when seen from the drive side, and the twine loop from the finished bale is laid from the left over the bill hook). In EP2861055 a right-hand knot and a left-hand knot are formed; the lower bill hook that closes the loop on the finished bale turns clockwise (seen from the drive side) to make a right-hand knot and the other bill hook turns counterclockwise to make a left-hand knot.

[0009] It has been noticed that with currently available binding twine left hand knots have a lower breaking resistance than right hand knots. This is due to the interaction between the bends of the twine within the knot and the twist of the twine. With left hand knots the outer fibers are over-stretched at a lower tension/force. When the outer fibers break the rest of fibers will also break. With right hand knots the tension is spread more evenly between the fibres, giving the twine loop a higher breaking force.

[0010] Further, it is noticed that loop knots tend to break at a higher force than conventional knots. The twine ends that form the loops are doubled in the turn of the knot, and as a result the bend in the twine has a larger radius. Therefore, there is less strain on the outer fibers in the turns of the twine within the knot. The tension in the fibers in the outer part of the twine is thus reduced in comparison with the conventional knot. Therefore, the loop knot will have a substantially higher twine load breaking strength.

[0011] A problem with existing double-knot binding systems is that the binding twines tend to break adjacent the knots at a force that is significantly lower than the ultimate breaking strength of the binding twine.

[0012] EP2721920 describes a knotter system for a baler in which the forces are regulated in the twine holder during formation of the first knot. The twine holder is partially released during formation of the knot, allowing the twine strands to pull through the twine holder so that these strands are not under high tension. When the knife engages the strands the strands bend and pull extra twine through the twine holder. The twine holder is then tightened again so that the knife cuts the twine. As a result, the knotter is able to form either a loop knot in which both ends of the twine are caught in the knot, or a half loop knot in which only one of the twine ends is longer and forms a loop.

[0013] A disadvantage of the system described in EP2721920 is that the amount of twine pulled through the twine holder depends on numerous variables such

as the sharpness of the knife, the physical properties of the twine (for example, its slipperiness) and the thickness of the twine. Furthermore, timing of the steps of the operation is critical and the mechanism to regulate the holding force is complicated. These factors all affect the reliability of the system.

[0014] It is an object of the present invention to provide a solution to one or more of the problems set out above, thereby allowing the compression of the bale to be increased without causing the twine loops to break and/or avoiding or mitigating one or more of the disadvantages of the system described in EP2721920.

[0015] According to certain aspects of the present invention there are provided a binding system for a baler, a baler that includes a binding system, and a method for binding a bale as defined by the claims.

[0016] In one embodiment, the invention relates to a binding system that comprises a knotter that includes a rotary bill hook, a twine holder, a twine cutter and a stripper element. The bill hook includes a catching element that is configured to adopt an open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot. The catching element is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position.

[0017] According to one aspect of the invention there is provided a baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder, and a twine cutter and a stripper element, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook by the stripper element, wherein the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position.

[0018] In one embodiment of the invention, the catch-

ing element is moved actively to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position. This provides an increased twine length when the knotter is in the second stripping off position, allowing the second knot to be tied as a loop knot. The procedure may also be applicable when the knotter is in the first stripping off position when tying the first loop knot.

[0019] Optionally, the opening element comprises a rotary drive element that drives movement of the catching element between the closed configuration and the open configuration, wherein the rotary drive element is rotatable relative to the bill hook while the bill hook is in the second position.

[0020] Optionally, the rotary drive element comprises a cam surface that engages a cam follower of the catching element.

[0021] Optionally, the opening element comprises a linear drive element that drives movement of the catching element between the closed configuration and the open configuration while the bill hook is in the second position.

[0022] Optionally, the catching element is moved to the open configuration by reducing or removing a biasing force applied by the resilient biasing element, so that the catching element opens in response to tension in the twine.

[0023] Optionally, the first and second knots are tied successively by a single bill hook, and the first and second knots are both loop knots.

[0024] According to another aspect of the invention there is provided a baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, and
- at least the second knot is a loop knot.

[0025] Optionally, the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp twines in at least one of the clamping notches against the retainer, and wherein the clamping notches are arranged asymmetrically around the periphery of the rotary disk.

[0026] Optionally, the drive for rotating the rotary disk includes a worm drive comprising a worm screw and a worm gear, wherein the worm screw is shifted axially to adjust the rotary position of the rotary disk between tying of the first and second knots.

[0027] Optionally, the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp a twine in at least one of the clamping notches against the retainer, wherein the retainer is configured so that the twine can be guided across the retainer in two different positions depending on the rotational position of the rotary disk, comprising a first position in which the twine can be cut by the twine cutter and a second position in which the twine cannot be cut by the twine cutter.

[0028] Optionally, the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knoter is stripped from the bill hook by the stripper element, wherein the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knoter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position.

[0029] Optionally, the baler further comprises the features of any one of claims 2 to 5.

[0030] Optionally, the first knot and the second knot are both loop knots.

[0031] Optionally, the first and second knots are both right-hand knots.

[0032] Optionally, the twine cutter is configured to cut the twine to provide a cut end, and wherein the twine cutter is displaced from the bill hook to provide a length L of twine between the cut end and the rotational axis of the bill hook, wherein the length L fulfils one or more of the following definitions:

- L is at least 1.3 times, or at least 1.6 times, or at least 2.0 times the length of the bill hook from the rotational axis to the tip of the bill hook;
- L is at least 0.5 times, or at least 0.6 times, or at least 0.75 times the length of twine needed to wrap circumferentially around the bill hook;
- L is at least 9 times, or at least 11 times, or at least 14 times the diameter of the twine when tied around a bound bale;
- L is at least 34mm, or at least 41 mm, or about 52mm.

[0033] Optionally, the binding system further comprises a twine guide located between the twine holder and the bill hook.

[0034] Optionally, the twine cutter is located between the twine guide and the twine holder.

[0035] According to another aspect of the invention there is provided a method of binding a bale in a baler comprising a bale forming channel, a reciprocating plunger that compresses bale material in the bale forming channel to form a bale, and a binding system that binds a bale in the bale forming channel, the binding system comprising a knoter that includes a rotary bill hook having a rotational axis, a catching element, a twine holder, a twine cutter and a stripper element, the method comprising passing the twines around opposite sides of the bale, tying a first knot and a second knot successively in the twines during one full operating cycle of the binding system, rotating the bill hook between a first position in which the bill hook engages the twines and a second position in which a knot is stripped from the bill hook by the stripper element, resiliently biasing the catching element towards a closed configuration to retain a twine on the bill hook while a knot is formed, and moving the catching element to an open configuration by operation of an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, to release the retained twine after the knot has been removed from the bill hook by the stripper element, so that a cut end of the twine is not pulled through the knot.

[0036] Optionally, the method further comprises driving movement of the catching element between the closed configuration and the open configuration by rotating an opening element relative to the bill hook while the bill hook is in the second position, said opening element comprising a rotary drive element.

[0037] Optionally, the method further comprises engaging a cam surface of the rotary drive element with a cam follower of the catching element.

[0038] Optionally, the method further comprises driving movement of the catching element between the closed configuration and the open configuration by operating an opening element comprising a linear drive element.

[0039] Optionally, the method further comprises moving the catching element to the open configuration by reducing or removing a biasing force applied by the resilient biasing element, so that the catching element opens in response to tension in the twine.

[0040] Optionally, the method further comprises tying the first and second knots successively by a single bill hook, wherein the first and second knots are both loop knots.

[0041] According to another aspect of the invention there is provided a method of binding a bale in a baler comprising a bale forming channel, a reciprocating plunger that compresses bale material in the bale forming channel to form a bale, and a binding system that binds a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knoter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding method comprises tying a first knot and a second knot successively in the twines during

one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, and
- at least the second knot is a loop knot.

[0042] Optionally, the twine holder comprises a rotary disk with a plurality of clamping notches arranged asymmetrically around a periphery of the rotary disk, and a retainer adjacent the periphery of the rotary disk, the method comprising driving rotation the rotary disk to clamp twines in at least one of the clamping notches against the retainer.

[0043] Optionally, the method further comprises driving the rotary disk with a worm drive comprising a worm screw and a worm gear, and shifting the worm screw axially to adjust the rotary position of the rotary disk between tying of the first and second knots.

[0044] Optionally, the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp a twine in at least one of the clamping notches against the retainer, the method comprising guiding the twine across the retainer in two different positions by adjusting the rotational position of the rotary disk, said positions comprising a first position in which the twine can be cut by the twine cutter and a second position in which the twine cannot be cut by the twine cutter.

[0045] Optionally, the method further comprises rotating the bill hook between a first position in which the bill hook engages the twines and a second position in which a knot is stripped from the bill hook by the stripper element, resiliently biasing the catching element towards a closed configuration to retain a twine on the bill hook while a knot is formed, and moving the catching element to an open configuration by operation of an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, to release the retained twine after the knot has been removed from the bill hook, so that the cut end of the twine is not pulled through the knot.

[0046] Optionally, the method further comprises the features of any one of claims 19 to 21.

[0047] Optionally, the first knot and the second knot are both tied as loop knots.

[0048] Optionally, the first and second knots are both tied as right-hand knots.

[0049] Optionally, the method further comprises cutting the twine to provide a length L of twine between a cut end of the twine and the rotational axis of the bill hook, wherein the length L fulfils one or more of the following definitions:

- L is at least 1.3 times, or at least 1.6 times, or at least 2.0 times the length of the bill hook from the rotational axis to the tip of the bill hook;
- L is at least 0.5 times, or at least 0.6 times, or at least

0.75 times the length of twine needed to wrap circumferentially around the bill hook:

- L is at least 9 times, or at least 11 times, or at least 14 times the diameter of the twine when tied around a bound bale;
- L is at least 34mm, or at least 41 mm, or about 52mm.

[0050] Optionally, the method further comprises guiding the twine by means of a twine guide located between the twine holder and the bill hook.

[0051] Optionally, the method further comprises cutting the twine between the twine guide and the twine holder.

[0052] Various embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figures 1 & 2 illustrate respectively a conventional type knot and a loop type knot;

Figure 3 illustrates a binding twine with a conventional twist pattern, called a Z-twist;

Figure 4 is a partially sectional side view of part of a baler;

Figure 5 depicts a twine loop tied around a finished bale and a pair of twines looped around a partially completed bale;

Figure 6 is an isometric view of a knotter from a first angle;

Figure 7 is an isometric view of the knotter from a second angle;

Figure 8 is an isometric view of the knotter from a third angle;

Figure 9 is a side view of a bill hook;

Figures 10a, 10b, 10C and 10D are isometric views of the bill hook in different operational conditions;

Figure 11 is a plan view of a twine disk;

Figure 12 is a side elevation of the knotter illustrating axial movement of the work wheel;

Figure 13 is an isometric view of the bill hook in different operational conditions;

Figure 14 is an isometric view of the knotter illustrating a length value L;

Figure 15 is an isometric view of an alternative knotter, and

Figures 16 and 17 are isometric views of another alternative knotter in different operational conditions.

[0053] A binding system for baler and a method for binding a crop bale are described in EP-1 584227-A1, the entire content of which is incorporated by reference herein.

[0054] The baler shown in figure 4 is similar in many respects to the baler described in EP-1584227-A1 and includes a bale case 22 that defines a bale chamber 26. Bale material is introduced into the bale chamber 26 through a feed duct 28. A plunger 30 compresses bale material in the bale chamber to produce a bale B. As the bale is produced, two twines 64,66 are drawn from twine sources 73,74 and laid along the upper and lower sides of the bale, as shown in figure 5. Upon completion of the bale, the twines 64, 66 are brought together by a needle 42 and the two twines 64,66 are tied together by a knotter 40, which is driven via a clutch 38, to form a twine loop 62 that is stretched around the bale B to maintain the bale material in compression after the bale is ejected from the bale case 22.

[0055] In this example, the knotter 40 includes a rotary bill hook 82, which is configured to tie two knots successively during each complete operating cycle. As illustrated in figure 5, a first knot 70 is tied to complete the twine loop 62 around the completed bale B and a second knot 72 is then tied to start a new twine loop 62a for the next bale. The twines are severed between the two knots 70, 72. In this example, the first and second knots 70,72 are both right-handed knots and they are tied successively by the same bill hook. Also, in this example, the second knot 72 is a loop knot, whereas the first knot 70 is a conventional knot. The strength of the twine loop is therefore limited by the strength of the conventional first knot 70, which has a lower breaking strength than the loop knot that forms the second knot 72. Alternatively, in certain embodiments of the invention, the first knot 70 and the second knot 72 may both be loop knots.

[0056] The binding system and the method for binding a bale according to the present invention are similar in most respects to the binding system and the method for binding a bale described in EP-1584227-A1. However, in certain embodiments of the present invention, the first knot and the second knot are both loop knots. Optionally, the first knot and the second knot are also both right-handed knots and optionally they are tied successively by the same bill hook. In these embodiments the inherent weakness of a conventional knot is avoided, providing a twine loop that has a greater breaking strength. This in turn means that the bale material can more highly compressed, leading to storage and transportation efficiencies, while the risk of the twine loop bursting is reduced. In certain other embodiments, the second knot 72 is a loop knot and the first knot 70 is a conventional knot.

[0057] A knotter 40 according to an embodiment of the present invention is shown in more detail in figures 6 to 8. The knotter 40 is similar in many respects to the knotter

described in EP-1584227-A1 and therefore will not be described in full detail.

[0058] The knotter 40 comprises a circular drive disk 76 that is attached through a hub 77 to a drive shaft 78. The knotter 40 also comprises a frame 80, a rotary bill hook 82 mounted on an end of a shaft 82a for rotation about an axis 84, and a multi-disk twine holder 86 that has a plurality of notches 87 in its perimeter for holding the twines against a retainer 120. A release arm 95 is pivotable to release the twines from the twine holder 86. The release arm 95 carries a cutter 94 for severing the twine strands and a stripper arm 92 for stripping a knot from the bill hook 82. Pivoting movement of the release arm 95 is controlled by a cam follower 89 that engages a cam track 90 in the drive disk 76.

[0059] The rotary bill hook 82, which is shown in more detail in figures 9 and 10a-10d, includes a fixed lower lip 83b and a pivotable upper lip 83a that moves between open and closed configurations and is controlled by a cam follower 85, which engages a cam track 91 provided on a collar 93 that surrounds the bill hook shaft 82a. Rotation of the bill hook 82 about the axis 84 is driven by a pinion 88 that engages first and second gear stretches 98,100 on the drive disk 76. The disks of the twine holder 86 are driven by a worm gear 101, a worm screw 102 and a bevel gear 103 that engages third and fourth gear stretches 104, 105 on the drive disk 76. Operation of the knotter 40 is substantially as described in EP-1584227-A1, except as described below.

[0060] In one embodiment of the invention, the knotter 40 is modified to provide an increased length L of twine between the bill hook 82 and the cut end of the twine in order to create two loop knots, so that the first knot 70 and the second knot 72 are both loop knots. This is achieved by placing the cutter 94 further from the bill hook 82, as described below. The twine holder 86 is also preferably located further away from the bill hook 82, so that it can hold the cut ends of the twines after the first knot 70 has been tied and the twines have been cut. Because the twines are severed further from the bill hook 82 and close to the twine holder 86, this ensures that there is an increased length of twine L between the bill hook and the cut end of the twine.

[0061] In one embodiment of the invention the twine cutter 94 is configured to cut the twine to provide a cut end, and wherein the twine cutter is displaced from the bill hook to provide a length L of twine between the cut end and the bill hook.

[0062] Optionally, the length L is at least 1.3 times, or at least 1.6 times, or at least 2.0 times the length of the bill hook from the rotational axis to the tip of the bill hook.

[0063] Optionally, the length L is at least 0.5 times, or at least 0.6 times, or at least 0.75 times the length of twine needed to wrap circumferentially around the bill hook.

[0064] Optionally, the length L is at least 9 times, or at least 11 times, or at least 14 times the diameter of the twine when tied around a bound bale.

[0065] Optionally, the length L is at least 34mm, or at least 41mm, or about 52mm.

[0066] In one embodiment, the invention provides a baler with a reciprocal plunger, a method and system that combines the advantages of binding a bale from two supplies per binding loop and binding the bale with two knots per binding loop whereby the knots are:

- of a loop type and
- are produced sequentially in one knotting cycle by one bill hook.

[0067] Preferably, the knots are both right-handed.

[0068] The key to forming a loop knot with a knotter 40 of the type described above is to have sufficient length of twine between the bill hook 82 and the position where the twine ends are severed from the twines held by the twine holder. Because the twine ends are severed near to the twine holder, the twine holder must also be placed substantially further from the bill hook.

[0069] The twine strands that form the loop of the loop knot are preferably released from the bill hook after the knot has been pulled off the bill hook. In one embodiment this is achieved by actively or passively releasing/opening a catching element 96 (also called a tongue or an upper lip 83a) that retains the twine on the bill hook 82 until just after the moment the knot is pushed/pulled off the bill hook by the stripper element 92. This prevents the risk that the loop will be stuck between the catching element 96 and the base of the bill hook 82, or that the ends of the twine will be pulled completely through the knot so that a conventional knot will be formed.

[0070] In one embodiment of the invention illustrated in figures 10A to 10D, the catching element 96 comprises the upper lip 83a of the bill hook 82, which is biased by a resilient biasing element 108 towards the closed configuration. The catching element 96 can be moved actively or passively to the open configuration.

[0071] In the system illustrated in figures 10A to 10D the catching element 96 comprises the upper lip 83a, which is moved actively to the open configuration. Opening of the catching element 96 is driven by an opening element 97 that acts against the resilient biasing element. In one embodiment, the opening element 97 comprises the cam track 91 that is provided on the collar 93.

[0072] In a conventional knotter the collar 93 is fixed to the frame 80 of the knotter. As the bill hook 82 rotates relative to the collar 93 the cam follower 85 runs along the cam track 91 and the catching element 96 opens when the cam follower encounters a part 91a of the cam track 91 that projects radially outwards from the collar.

[0073] In an embodiment of the invention illustrated in figures 10a-10D and 13, the collar 93 is modified so as to be rotatable relative to the frame 80, as indicated in figure 13 by a curved arrow D. An actuator (not shown) may be provided to control rotary movement of the collar 93, or rotation may be driven mechanically from the drive disk 76. By rotating the collar 93 the catching element 96

(upper lip 83a) can be opened without rotation of the bill hook 82 relative to the frame 80.

[0074] The bill hook 82 is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook 82 by the stripper arm 92. The catching element 96 can be configured in a closed configuration to retain a twine to the bill hook 82 or an open configuration to release the twine from the bill hook 82. The catching element 96 is configured to adopt the open configuration to release the retained twine from the bill hook 82 after the knot is removed from the bill hook 82 by the stripper arm 92, so that the cut end of the twine is not pulled through the knot. In this embodiment the catching element 96 is biased by the resilient biasing element 108 towards the closed configuration and is moved to the open configuration by the opening element 97, which comprises the collar 93 and the cam follower 85. The catching element 96 can thus be opened to release the twine without rotating the bill hook 82 beyond the second position.

[0075] In another embodiment of the invention, also illustrated in figure 13, the collar 93 is modified so that it can move relative to the frame 80 in a linear direction, parallel to the axis 84 of the bill hook 82, as indicated by a straight arrow E. An actuator (not shown) may be provided to control linear movement of the collar 93, or linear movement of the collar 93 may be driven mechanically from the drive disk 76. For example, an actuator (not shown) connected to the collar 93 can be activated to push the collar 93 downwards so that a bevelled portion 93a of the collar engages the cam follower 85 at the rear end of the upper lip 83a, causing the catching element 96 to open. The catching element 96 can therefore be opened either with or without rotation of the bill hook 82 relative to the frame 80. If an actuator is used, the actuator can comprise a linear actuator, for example an electric or hydraulic actuator, or it can be driven mechanically on basis of the rotation of the disk 76.

[0076] In each of the above embodiments opening of the catching element 96 can be controlled to release the twines from the bill hook after the knot has been formed, to increase the length L of twine between the bill hook and the cut ends of the twines. As illustrated in figure 14, the length L of twine between the bill hook and the cut ends of the twines can be equal to the distance between the axis 84 of the bill hook 82 and the position of the cutter 94 when it cuts the twines.

[0077] Alternatively, the catching element can be moved passively to the open configuration. For example, opening of the catching element can be achieved by inactivating the resilient biasing element or reducing/counteracting the biasing force, so that the catching element is moved to the open configuration by the tension in the twine. Inactivating the resilient biasing element or reducing/counteracting the biasing force can be achieved for example by modifying the configuring the resilient element 108 so that only at the position of the bill hook 82

where the knot is stripped off (and not if it is turned to form the knot) the catching element 83a is not affected by the resilient biasing element 108 and the catching element 83a is free to move (partly) upward. When the knot is formed and not yet stripped off the bill hook 82 the twine that is wound around the bill hook 82 will hold the catching element 83a down. As soon as the knot is stripped off the bill hook 82 the catching element 83a is then free to move upward. The upward movement of the catching element 83a may result as a reaction to the pulling force of the twine loop but could also be assisted by an additional counter-biasing resilient element.

[0078] If the bill hook 82 is turned for forming the loop the resilient biasing element 108 will force the catching element down.

[0079] The process of producing the knot is well described in text and pictures of WO2018202588A1, the entire content of which is incorporated by reference herein.

[0080] Conventionally, the twine holder 86 is mounted next to the bill hook 82. In another embodiment of the invention illustrated in figure 15 the severing knife 94 and twine holder 86 are placed further away from the bill hook 82, i.e., significantly further than the distances found in a conventional knotter.

[0081] In an embodiment of the present invention the twine holder 86 may be modified to provide a twine guide 86a, for example by removing or modifying the retainer 120, so that the notches 87 in the periphery of the guide disk serve only to bring the twines into a correct position in relation to the bill hook 82 and the opened tongue/catching element 83a. An alternative twine holder 86b is then provided a short distance away from the bill hook 82 and the cutter 94 is repositioned so that it is located between the twine guide 86a and the twine holder 86b. The twine is held by the twine holder 86b, which is positioned further away from the bill hook 82 than the twine guide 86a and the twine is severed between the twine guide 86a and the twine holder 86b. As a result, the twine is severed beyond the position of a conventional disk/twine holder (seen from the bill hook) to provide an increased length L of twine between the bill hook 82 and the cut ends of the twines.

[0082] In this embodiment, the severing device or cutter 94 is optionally not mounted directly on the stripper arm 92 that strips the knot from the bill hook 82, but comprises a separate cutter mechanism located further from the bill hook. By comparison, in a conventional knotter the cutter 94 is fixedly connected to the stripper arm 92.

[0083] In another embodiment of the invention, the twine holder 86 is configured to release the twines just after the bill hook 82 has finished its second turn to complete the knot and before or at the moment the knot is pushed/pulled off the bill hook 82 by the stripper arm 92. This helps to prevent the possibility that there will be loose twine ends or "tails" (waste) that will pollute the fodder or the environment. By releasing the twines the loop of the second knot of the binding cycle will have longer ends.

[0084] For example, in an embodiment of the invention, the releasing of the twine ends by the twine holder 86 is done by positioning the notches 87a, 87b in the twine holder disk 86 asymmetrically (not at 90 degrees), as illustrated in Fig. 11, so as to have the twines held for the first knot between the first notch 87a and the retainer 120 and to have the second notch 87b positioned (at rest) just beyond the clamping retainer 120. For example, the notches 87a, 87b may be displaced at angles of approximately 65-70 degrees and 110-115 degrees, as illustrated in Fig. 11.

[0085] In another embodiment, as illustrated in Figure 12, the releasing of the twine ends by the twine holder can also be done by moving the worm screw 102 axially along its turning axis at the end of the second turn, so as to give the holding disk 86 an extra forward rotary movement and to release the twine ends just before the second knot is pushed/pulled off the bill hook 82, so that the twine will not be cut during stripping off of the second knot. Axial movement of the worm screw 102 is shown in Figure 12 by a straight double-headed arrow A, and the resulting additional rotation of the worm gear 101, which drives rotation of the holding disk 86, is shown by a curved double-headed arrow C. Axial movement of the worm screw 102 may be driven by another component of the knotter, for example the stripper arm 92. After formation of the second knot the worm screw 102 will be positioned axially back to its original position, for example by a spring or other resilient component.

[0086] In another embodiment, as illustrated in Figures 16 & 17, the retainer 120 may be configured so that the twine 64 is guided across the retainer 120 in two different positions, depending on the rotational position of the guide disk 86. For example, as shown in Figure 16 in a first position of the guide disk 86 for tying the first knot the twine 64 is guided across the retainer 120 in a high position, where it can be contacted by the cutter 94. As a result, the twine 64 is cut when the cutter 94 is activated. Alternatively, as shown in Figure 17 in a second position of the guide disk 86 for tying the second knot the twine 64 is guided across the retainer 120 in a low position, where it cannot be contacted by the cutter 94. As a result, the twine 64 is not cut by the cutter 94, allowing it to be pulled through the guide disk 86. The retainer 120 does not have a cutting edge and does not cut the twine 64.

[0087] Numerous different embodiments or alternative features of the invention are described above. It should be understood that any two or more of these different embodiments or features of the invention may be combined in a single binding system. For example, the modified bill hook shown in Figs. 10a-10d and 13 may be combined with one or more of the asymmetric twine holder disk 86 shown in Fig. 11, the modified worm wheel 101 and screw 102 shown in Fig. 12, the twine guide 86a and twine holder 86b and cutter 94 shown in Fig. 15 and the modified retaining element 120 shown in Figs. 16 & 17. Any combination of two or more of these features is possible and is disclosed herein.

[0088] The invention can be arranged as follows:

1. A baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder, a twine cutter and a stripper element, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook by the stripper element, wherein the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position.

2. A baler according to clause 1, wherein the opening element comprises a rotary drive element that drives movement of the catching element between the closed configuration and the open configuration, wherein the rotary drive element is rotatable relative to the bill hook while the bill hook is in the second position.

3. A baler according to clause 2, wherein the rotary drive element comprises a cam surface that engages a cam follower of the catching element.

4. A baler according to clause 1, wherein the opening element comprises a linear drive element that drives movement of the catching element between the closed configuration and the open configuration while the bill hook is in the second position.

5. A baler according to clause 1, wherein the catching element is moved to the open configuration by reducing or removing a biasing force applied by the resilient biasing element, so that the catching element opens in response to tension in the twine.

6. A baler according to any preceding clause, wherein:

- the first and second knots are tied successively by a single bill hook, and

- the first and second knots are both loop knots.

7. A baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, and
- at least the second knot is a loop knot.

8. A baler according to any preceding clause, wherein the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp twines in at least one of the clamping notches against the retainer, and wherein the clamping notches are arranged asymmetrically around the periphery of the rotary disk.

9. A baler according to clause 8, wherein the drive for rotating the rotary disk includes a worm drive comprising a worm screw and a worm gear, wherein the worm screw is shifted axially to adjust the rotary position of the rotary disk between tying of the first and second knots.

10. A baler according to any preceding clause, wherein the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp a twine in at least one of the clamping notches against the retainer, wherein the retainer is configured so that the twine can be guided across the retainer in two different positions depending on the rotational position of the rotary disk, comprising a first position in which the twine can be cut by the twine cutter and a second position in which the twine cannot be cut by the twine cutter.

11. A baler according to clause 7, wherein the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook by the stripper element, wherein the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut

end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position.

12. A baler according to clause 11, further comprising the features of any one of clauses 2 to 5.

13. A baler according to any preceding clause, wherein the first knot and the second knot are both loop knots.

14. A baler according to any preceding clause, wherein the first and second knots are both right-hand knots.

15. A baler according to any preceding clause, wherein the twine cutter is configured to cut the twine to provide a cut end, and wherein the twine cutter is displaced from the bill hook to provide a length L of twine between the cut end and the rotational axis of the bill hook, wherein the length L fulfils one or more of the following definitions:

- L is at least 1.3 times, or at least 1.6 times, or at least 2.0 times the length of the bill hook from the rotational axis to the tip of the bill hook;
- L is at least 0.5 times, or at least 0.6 times, or at least 0.75 times the length of twine needed to wrap circumferentially around the bill hook;
- L is at least 9 times, or at least 11 times, or at least 14 times the diameter of the twine when tied around a bound bale;
- L is at least 34mm, or at least 41mm, or about 52mm.

16. A baler according to any one of the preceding clauses, wherein the binding system further comprises a twine guide located between the twine holder and the bill hook.

17. A baler according to clause 16, wherein the twine cutter is located between the twine guide and the twine holder.

18. A method of binding a bale in a baler comprising a bale forming channel, a reciprocating plunger that compresses bale material in the bale forming channel to form a bale, and a binding system that binds a bale in the bale forming channel, the binding system comprising a knoter that includes a rotary bill hook having a rotational axis, a catching element, a twine holder, a twine cutter and a stripper element, the method comprising passing the twines around opposite sides of the bale, tying a first knot and a second knot successively in the twines during one full operating cycle of the binding system, rotating the bill hook between a first position in which the bill hook engages the twines and a second position in which a knot is stripped from the bill hook by the stripper element, resiliently biasing the catching el-

ement towards a closed configuration to retain a twine on the bill hook while a knot is formed, and moving the catching element to an open configuration by operation of an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, to release the retained twine after the knot has been removed from the bill hook by the stripper element, so that a cut end of the twine is not pulled through the knot.

19. A method according to clause 18, further comprising driving movement of the catching element between the closed configuration and the open configuration by rotating an opening element relative to the bill hook while the bill hook is in the second position, said opening element comprising a rotary drive element.

20. A method according to clause 19, further comprising engaging a cam surface of the rotary drive element with a cam follower of the catching element.

21. A method according to clause 18, further comprising driving movement of the catching element between the closed configuration and the open configuration by operating an opening element comprising a linear drive element.

22. A method according to clause 18, further comprising moving the catching element to the open configuration by reducing or removing a biasing force applied by the resilient biasing element, so that the catching element opens in response to tension in the twine.

23. A method according to any one of clause 18 to 22, further comprising:

- tying the first and second knots successively by a single bill hook, wherein the first and second knots are both loop knots.

24. A method of binding a bale in a baler comprising a bale forming channel, a reciprocating plunger that compresses bale material in the bale forming channel to form a bale, and a binding system that binds a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knoter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding method comprises tying a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, and
- at least the second knot is a loop knot.

25. A method according to any one of clauses 18 to 24, wherein the twine holder comprises a rotary disk with a plurality of clamping notches arranged asymmetrically around a periphery of the rotary disk, and

a retainer adjacent the periphery of the rotary disk, the method comprising driving rotation the rotary disk to clamp twines in at least one of the clamping notches against the retainer.

26. A method according to clause 25, further comprising driving the rotary disk with a worm drive comprising a worm screw and a worm gear, and shifting the worm screw axially to adjust the rotary position of the rotary disk between tying of the first and second knots.

27. A method according to any one of clauses 18 to 26, wherein the twine holder comprises a rotary disk with a plurality of clamping notches, a retainer adjacent a periphery of the rotary disk, and a drive for rotating the rotary disk to clamp a twine in at least one of the clamping notches against the retainer, the method comprising guiding the twine across the retainer in two different positions by adjusting the rotational position of the rotary disk, said positions comprising a first position in which the twine can be cut by the twine cutter and a second position in which the twine cannot be cut by the twine cutter.

28. A method according to clause 27, further comprising rotating the bill hook between a first position in which the bill hook engages the twines and a second position in which a knot is stripped from the bill hook by the stripper element, resiliently biasing the catching element towards a closed configuration to retain a twine on the bill hook while a knot is formed, and moving the catching element to an open configuration by operation of an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, to release the retained twine after the knot has been removed from the bill hook, so that the cut end of the twine is not pulled through the knot.

29. A method according to clause 28, further comprising the features of any one of clauses 19 to 21.

30. A method according to any one of clauses 18 to 29, wherein the first knot and the second knot are both tied as loop knots.

31. A method according to any one of clauses 18 to 30, wherein the first and second knots are both tied as right-hand knots.

32. A method according to any one of clauses 18 to 31, further comprising cutting the twine to provide a length L of twine between a cut end of the twine and the rotational axis of the bill hook, wherein the length L fulfils one or more of the following definitions:

- L is at least 1.3 times, or at least 1.6 times, or at least 2.0 times the length of the bill hook from the rotational axis to the tip of the bill hook;
- L is at least 0.5 times, or at least 0.6 times, or at least 0.75 times the length of twine needed to wrap circumferentially around the bill hook;
- L is at least 9 times, or at least 11 times, or at least 14 times the diameter of the twine when

tied around a bound bale;

- L is at least 34mm, or at least 41mm, or about 52mm.

33. A method according to any one of clauses 18 to 32, further comprising guiding the twine by means of a twine guide located between the twine holder and the bill hook.

34. A method according to clauses 33, further comprising cutting the twine between the twine guide and the twine holder.

Claims

1. A baler comprising a bale forming channel, a reciprocating plunger configured to compress bale material in the bale forming channel to form a bale, and a binding system for binding a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding system is configured to tie a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

- the first and second knots are tied successively by a single bill hook, the bill hook is rotatable between a first position in which the bill hook engages the twines and a second position in which a knot formed by the knotter is stripped from the bill hook by the stripper element, wherein the bill hook includes a catching element that is configurable in a closed configuration to retain a twine to the bill hook and in an open configuration to release the twine from the bill hook, wherein the catching element is configured to adopt the open configuration to release a retained twine from the bill hook after a knot formed by the knotter is removed from the bill hook by the stripper element, so that the cut end of the twine is not pulled through the knot, and wherein the catching element is biased by a resilient biasing element towards the closed configuration and is moved to the open configuration by an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, and
- at least the second knot is a loop knot.

2. A baler according to claim 1, wherein the opening element comprises a rotary drive element that drives movement of the catching element between the closed configuration and the open configuration, wherein the rotary drive element is rotatable relative to the bill hook while the bill hook is in the second

position.

3. A baler according to claim 2, wherein the rotary drive element comprises a cam surface that engages a cam follower of the catching element.

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4. A baler according to claim 1, wherein the opening element comprises a linear drive element that drives movement of the catching element between the closed configuration and the open configuration while the bill hook is in the second position.

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5. A baler according to claim 1, wherein the catching element is moved to the open configuration by reducing or removing a biasing force applied by the resilient biasing element, so that the catching element opens in response to tension in the twine.

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6. A baler according to any one of the preceding claims, wherein the first knot and the second knot are both loop knots.

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7. A baler according to any preceding claim, wherein the first and second knots are both right-hand knots.

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8. A method of binding a bale in a baler comprising a bale forming channel, a reciprocating plunger that compresses bale material in the bale forming channel to form a bale, and a binding system that binds a bale in the bale forming channel with a pair of twines that pass around opposite sides of the bale, the binding system comprising a knotter that includes a rotary bill hook that has a rotational axis, a twine holder and a twine cutter, wherein the binding method comprises tying a first knot and a second knot successively in the twines during one full operating cycle of the binding system, wherein:

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- the first and second knots are tied successively by a single bill hook, and further comprising rotating the bill hook between a first position in which the bill hook engages the twines and a second position in which a knot is stripped from the bill hook by the stripper element, resiliently biasing the catching element towards a closed configuration to retain a twine on the bill hook while a knot is formed, and moving the catching element to an open configuration by operation of an opening element that acts against the resilient biasing element, without rotating the bill hook beyond the second position, to release the retained twine after the knot has been removed from the bill hook, so that the cut end of the twine is not pulled through the knot, and
- at least the second knot is a loop knot.

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9. A method according to claim 8, further comprising driving movement of the catching element between

the closed configuration and the open configuration by rotating an opening element relative to the bill hook while the bill hook is in the second position, said opening element comprising a rotary drive element.

10. A method according to claim 9, further comprising engaging a cam surface of the rotary drive element with a cam follower of the catching element.

11. A method according to claim 8, further comprising driving movement of the catching element between the closed configuration and the open configuration by operating an opening element comprising a linear drive element.

12. A method according to any one of claims 8 to 11, wherein the first knot and the second knot are both tied as loop knots.

13. A method according to any one of claims 8 to 12, wherein the first and second knots are both tied as right-hand knots.

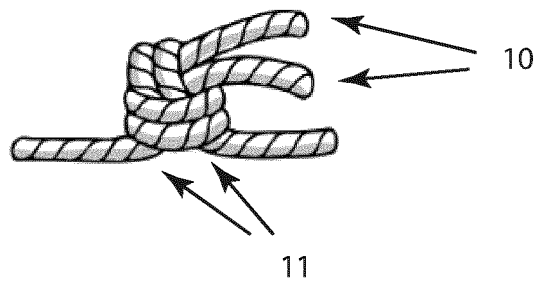


Fig. 1

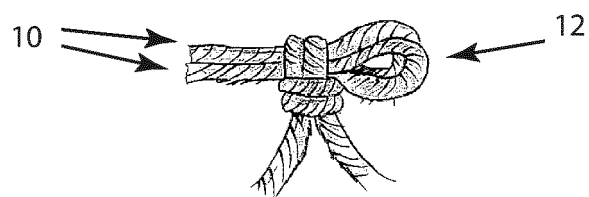


Fig. 2



Fig. 3

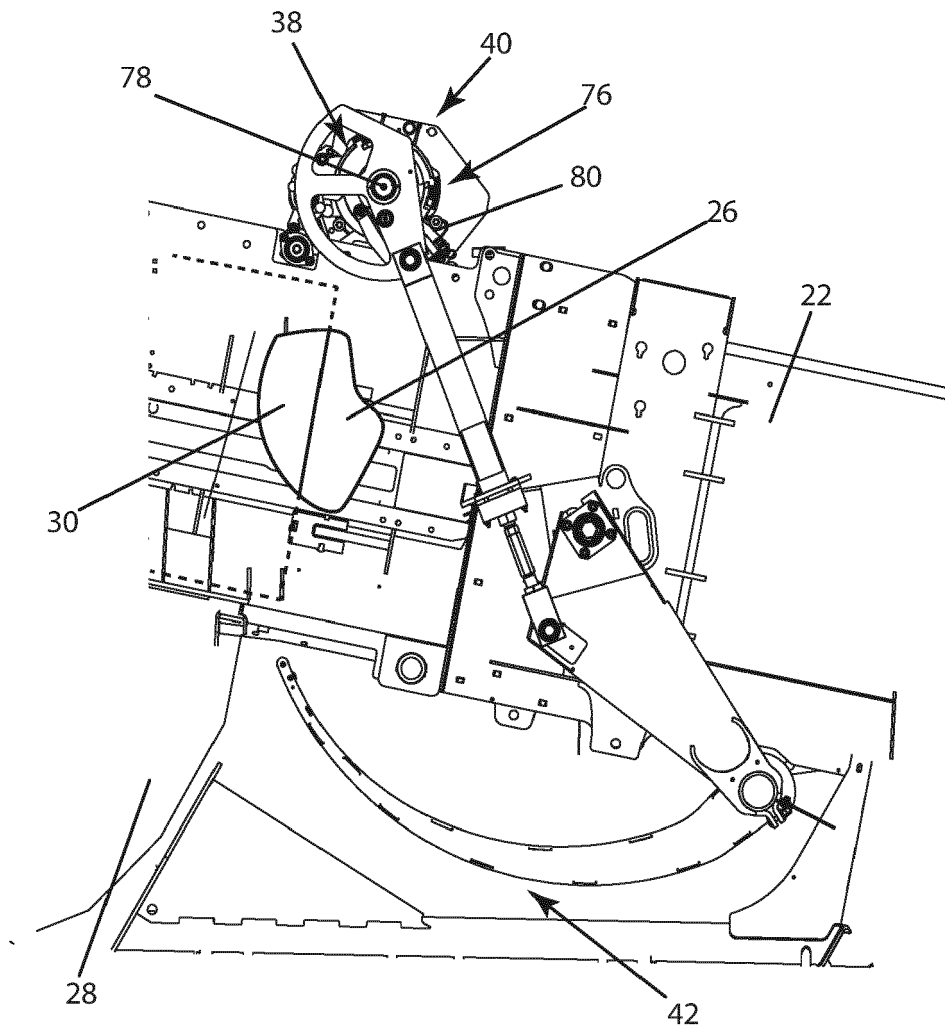


Fig.4

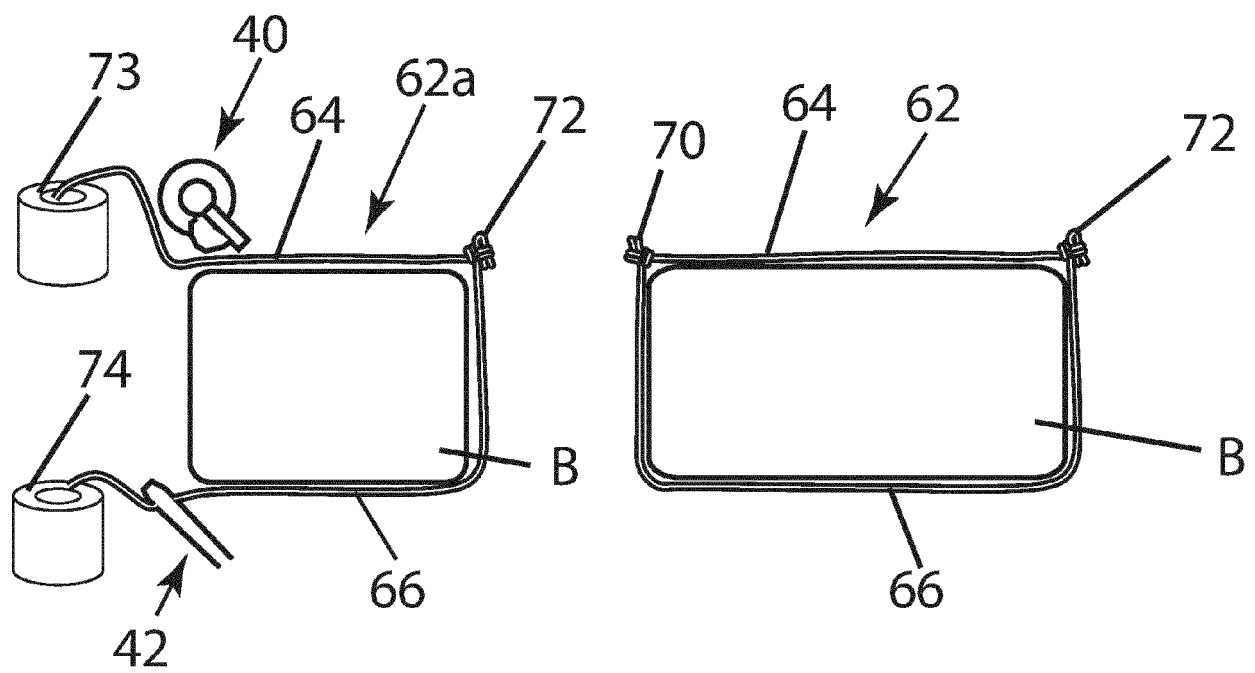


Fig. 5

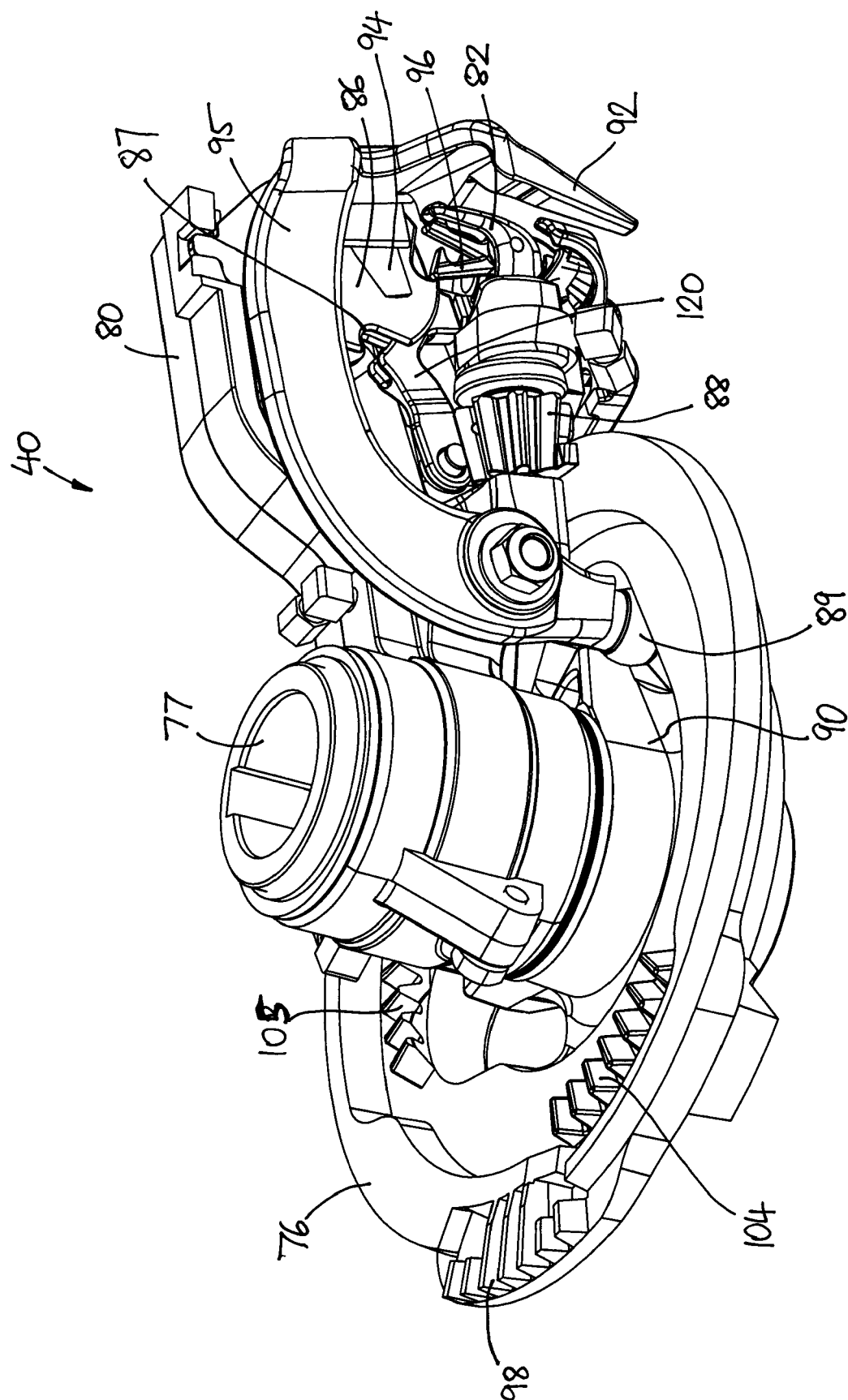


Fig. 6

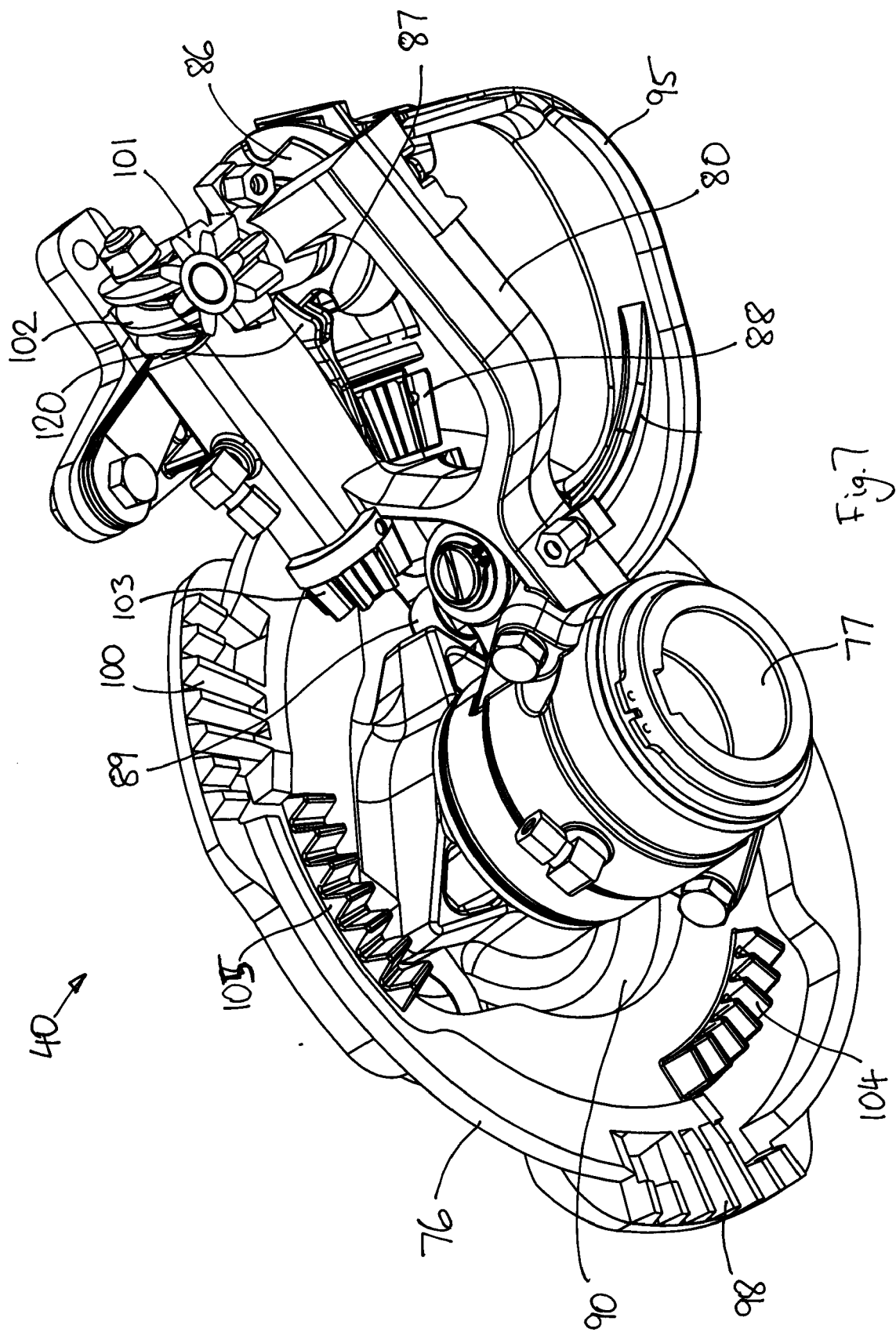
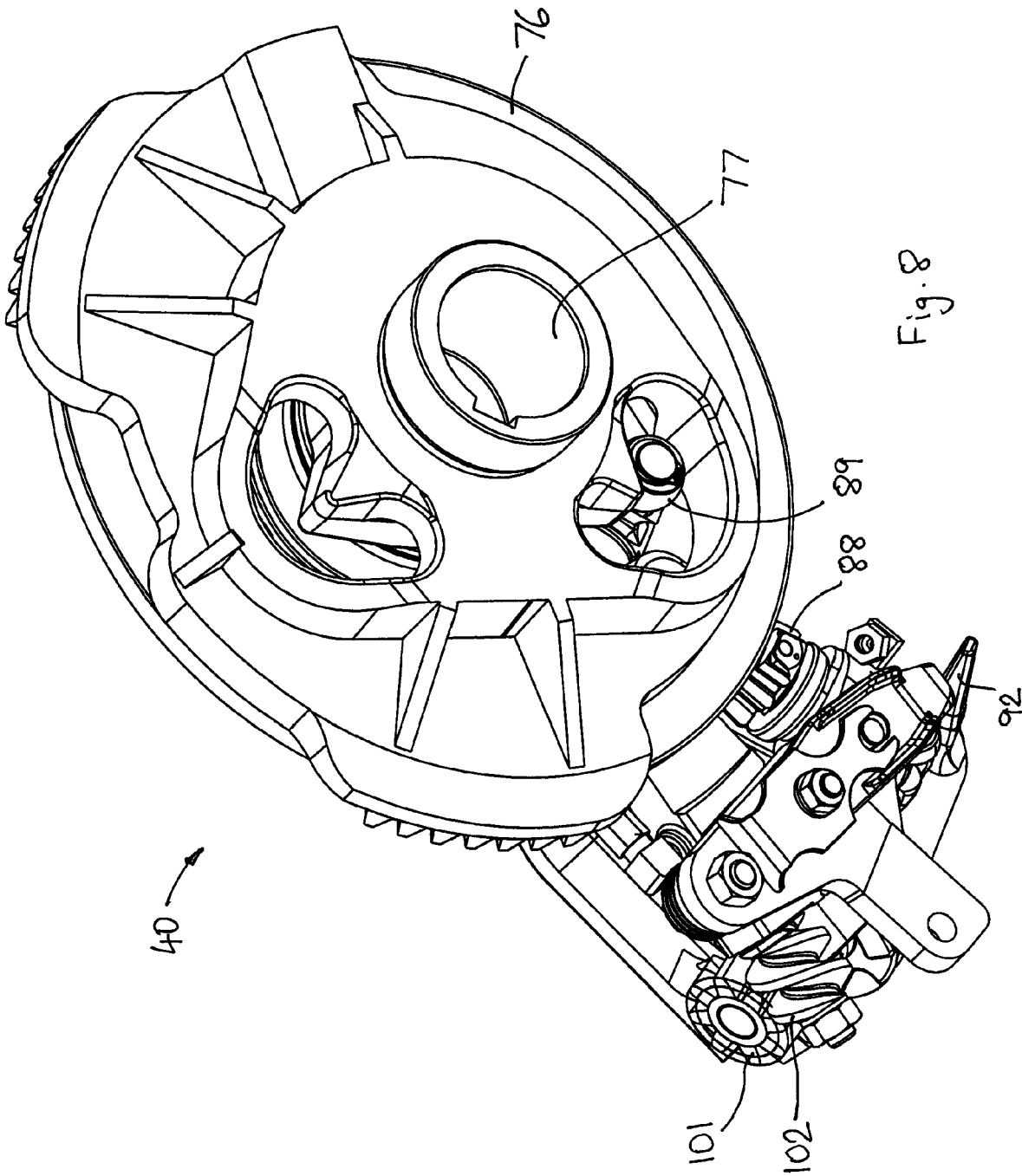


Fig. 7



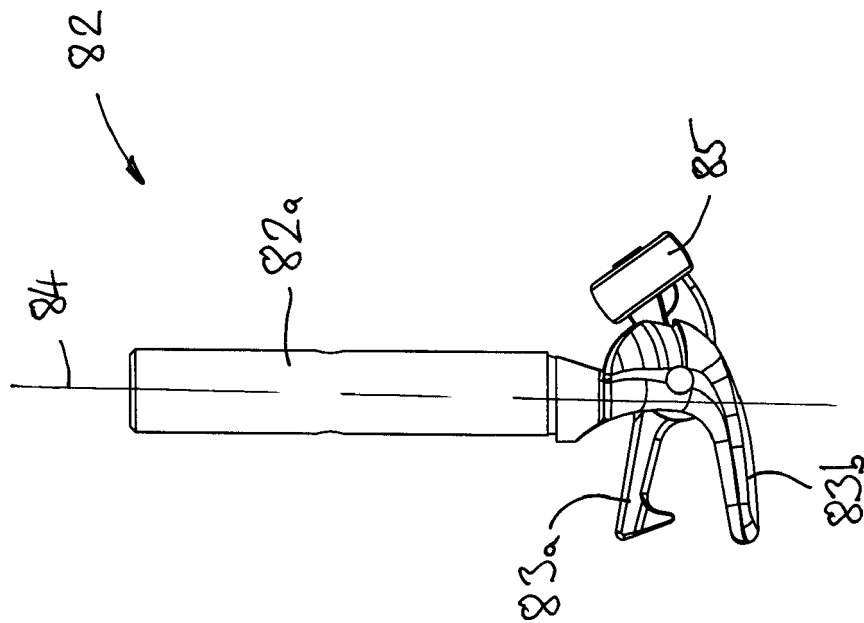


Fig. 9

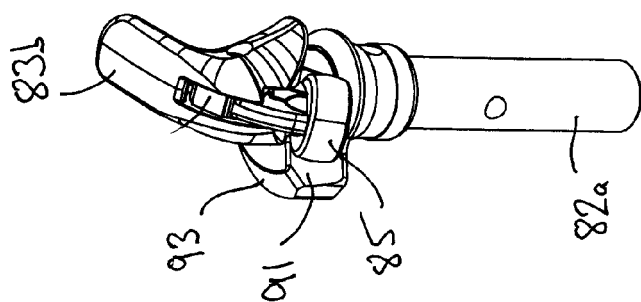


Fig. 10a

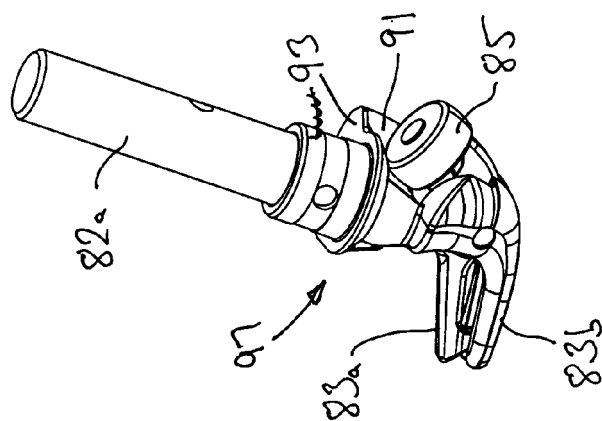


Fig. 10b

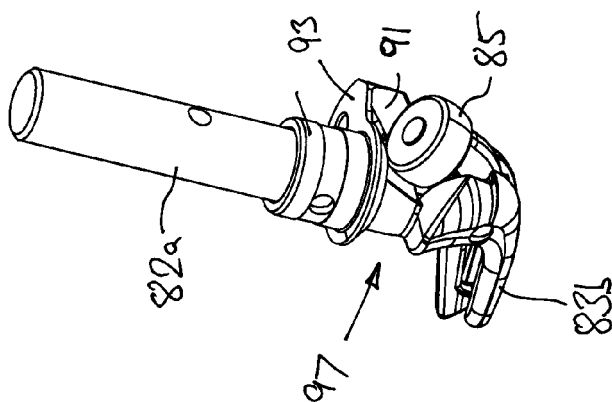


Fig. 10c

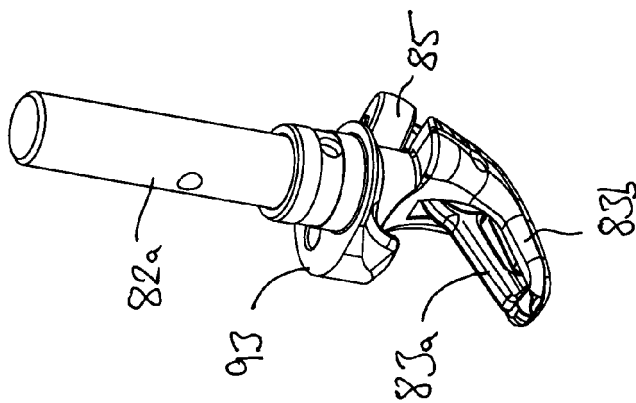


Fig. 10d

Figure 11

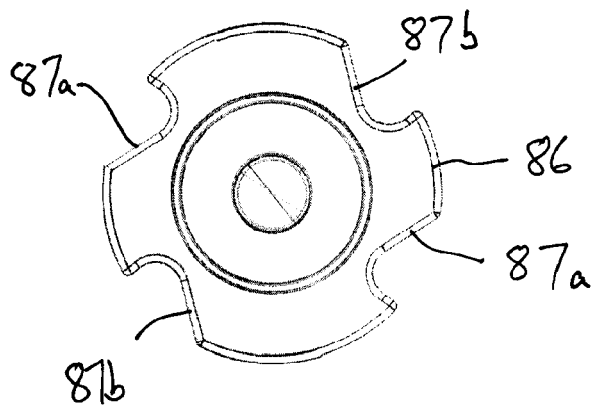
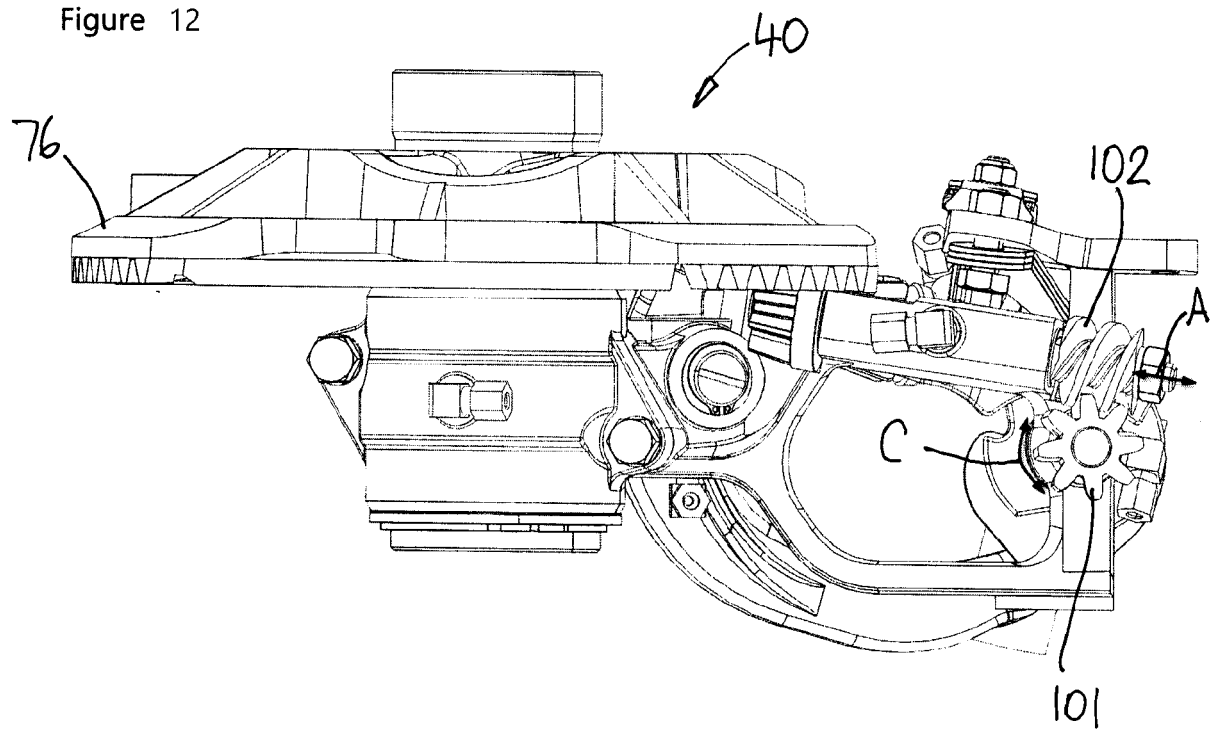


Figure 12



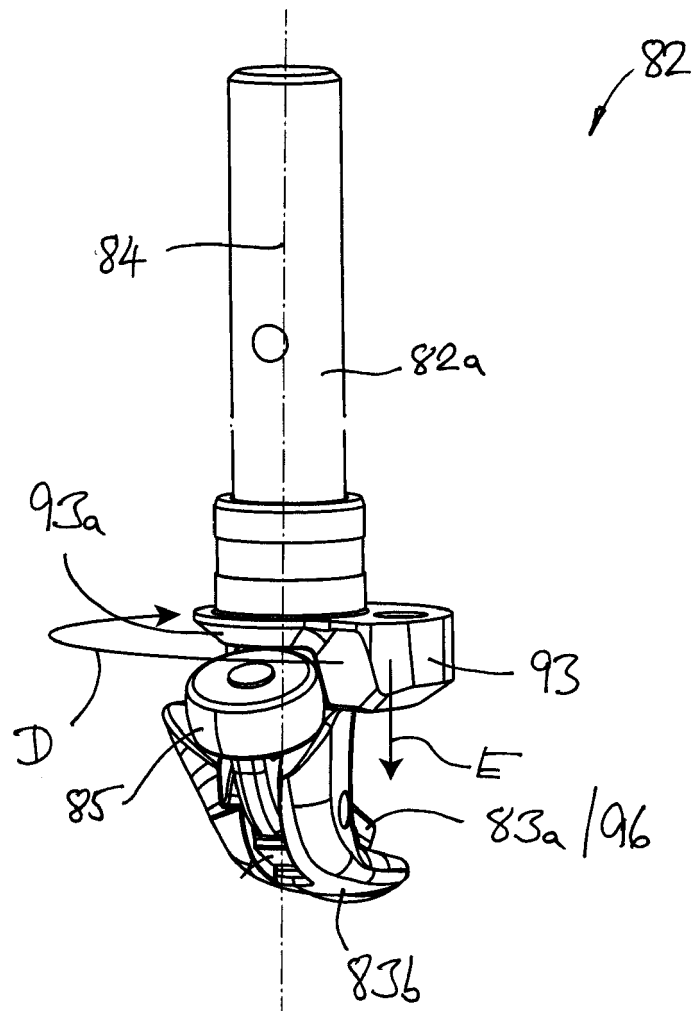
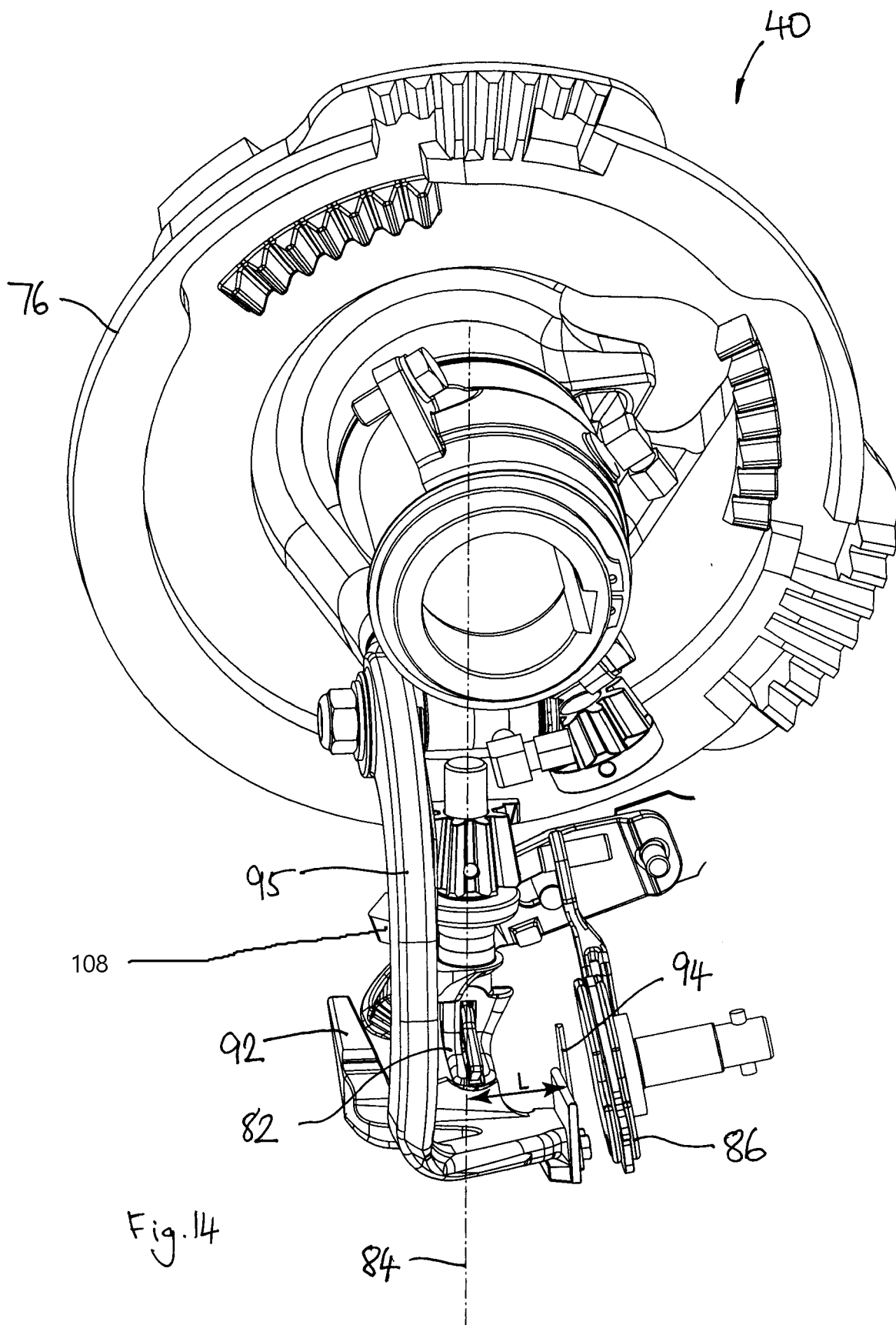


Fig. 13



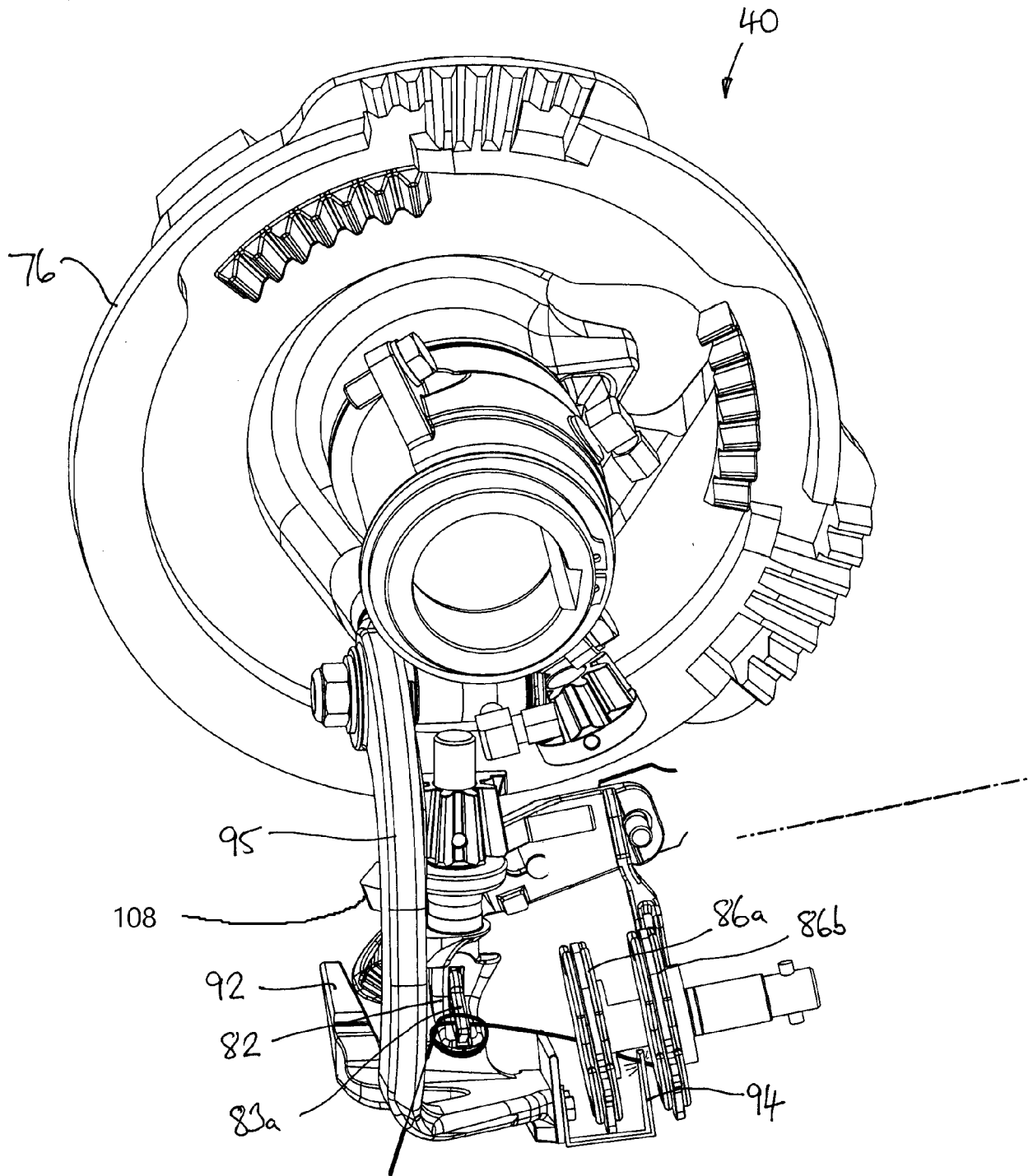


Fig. 15

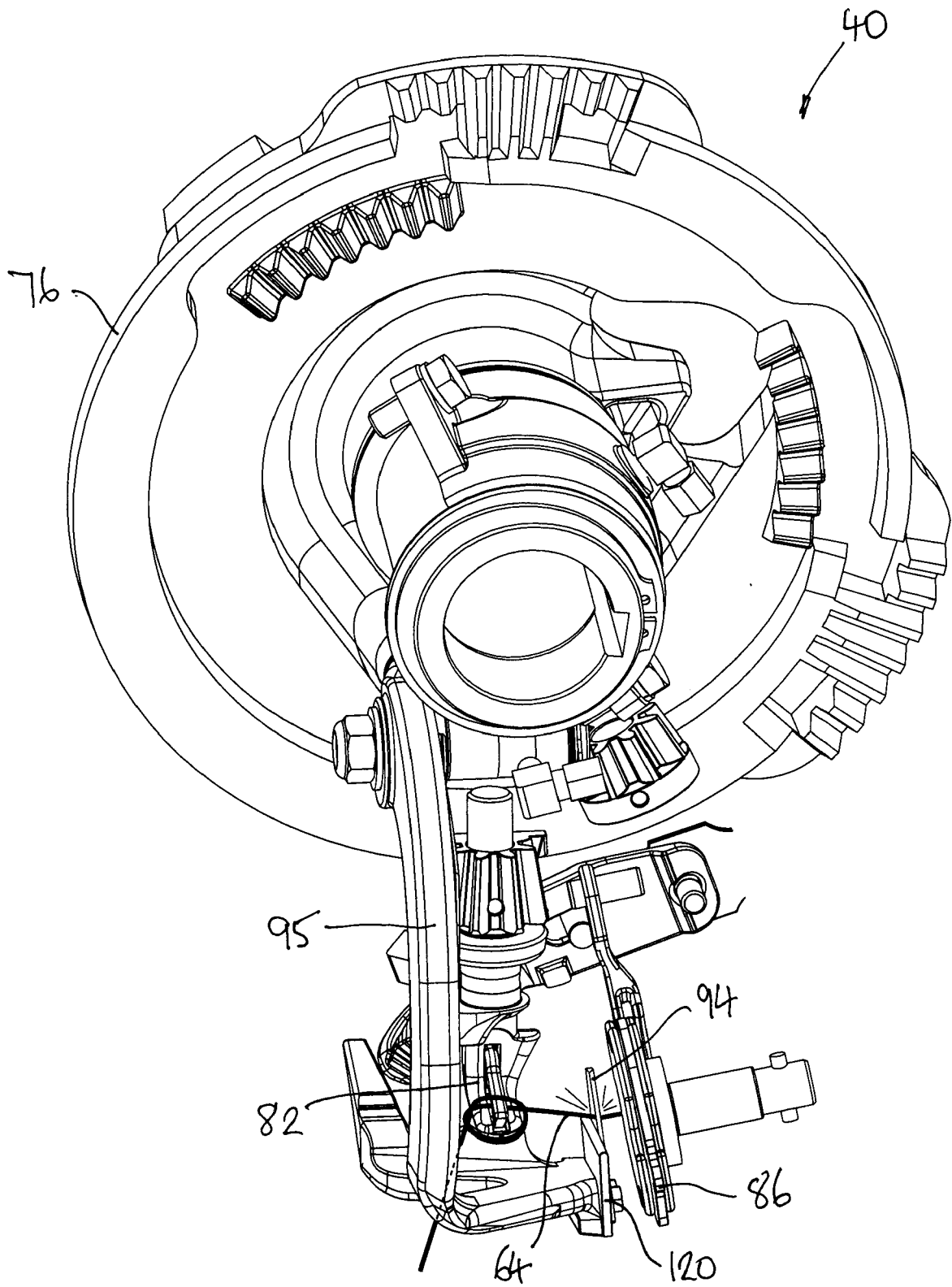


Fig.16

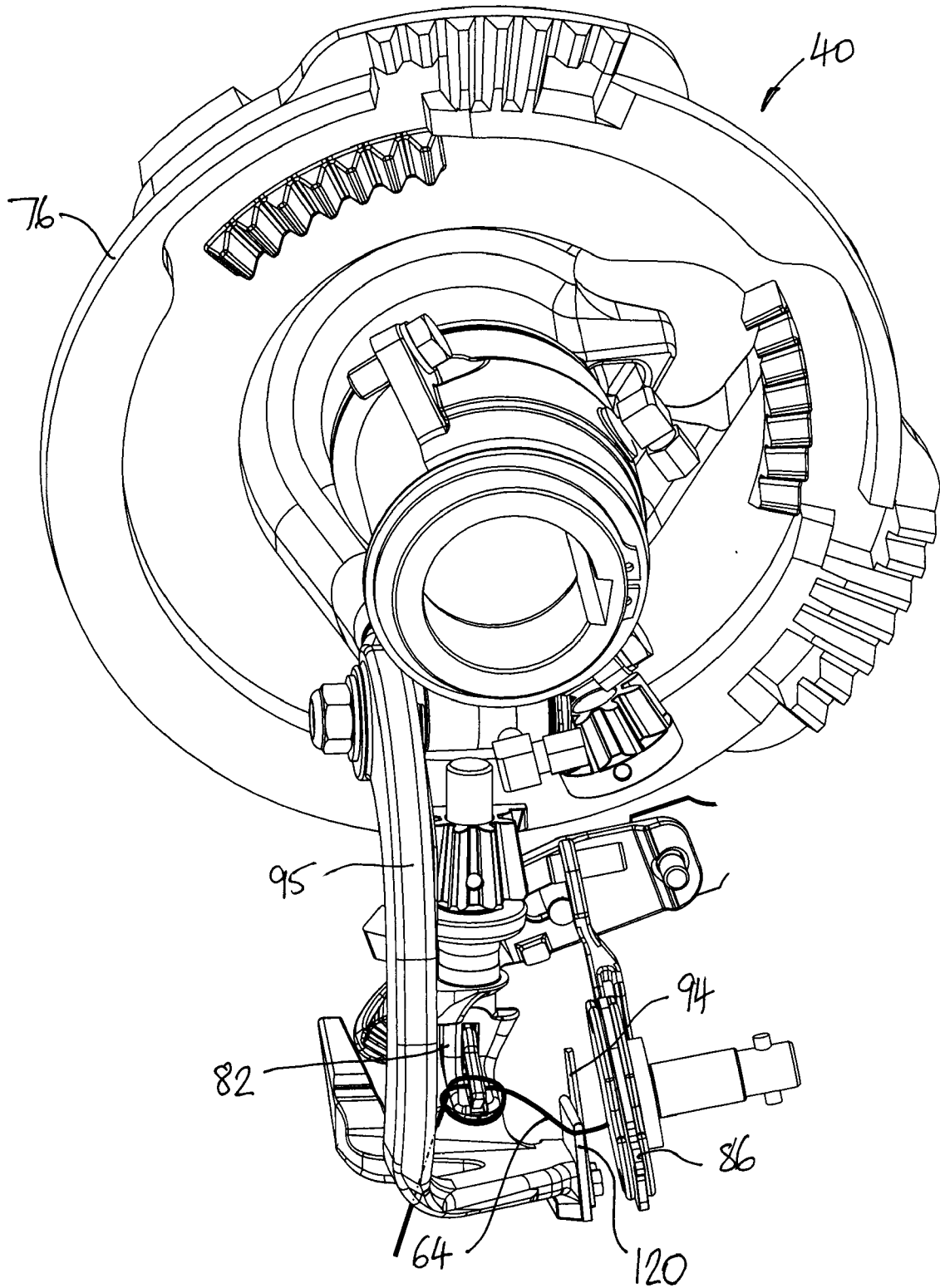


Fig. 17



EUROPEAN SEARCH REPORT

Application Number

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| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|--|--|---|---|
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